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Peer Group Effects on the Academic Performance of Italian Students

Abstract. We analyse peer effects among students of a middle-sized Italian public university. We explain students' average grade in exams passed during their Second Level Degree course on the basis of their pre-determined measures of abilities, personal characteristics and peer group abilities. Thanks to a rich administrative dataset, we are able to build a variety of definitions of peer groups, describing different kinds of students' interaction, based on classes attended together or exams taken in the same session. Self-selection problems are handled through Two-Stage Least Squares estimations using as an instrument, the exogenous assigning of students to different teaching classes in the compulsory courses attended during their First Level Degree course. We find statistically significant positive peer group effects, which are robust to the different definitions of peer group and to different measures of abilities.

JEL Classification: I21; Z13; J24.

1. Introduction

Educational economists have highlighted, in theoretical and empirical studies, the relevance of peer group quality to student performance (Epple and Romano, 1998; Hoxby, 2000). A peer group affects student achievement in several ways: members of a group interact in learning, help each other in their studies, share important information, impose externalities on others by behaving well or badly (for example, a noisy student disrupts the study environment) or by allowing teachers to go deeper in subjects, contribute to the formation of values and aspirations, and so on.

Understanding the nature and the magnitude of peer group effects in education is crucial for the "productivity" of educational processes and the organizational design of school systems. For example, in order to improve student outcomes, it is important to know which inputs influence their performance most and the relative importance of peer effects compared to other inputs, such as teacher quality or school resources. Peer effects are also important in school design. If peer effects are at work, educational outcomes are affected by how students are arranged across classes and the desirability of comprehensive schools (which mix students of different abilities together) or stratified schools (which tend to aggregate students according to their abilities) depends on the magnitude and non-linearity of peer effects. Further more, the selectivity of university admission policies produces different results in the presence of peer effects. More importantly, the nature of peer effects also has fundamental implications in a family's choice with regards whether parents consider that their offspring would benefit from schools which sort students according to their abilities.

Starting from the classical study of Coleman *et al.* (1966), a host of works have analysed the effects of peer group on children's achievement and educational outcomes (Betts and Morell, 1999; Hoxby, 2000; Angrist and Lang, 2004; Hanushek *et al.*, 2003) and on college students' grades and choices of fields of study (Sacerdote, 2001; Zimmerman, 2003; De Giorgi, Pellizzari and Redaelli, 2006; Foster, 2006), but several problems and controversies are still unresolved. Some of these studies show that peer effects are statistically and economically significant in a variety of educational contexts and that students tend to perform better if the quality of their peer group is higher (Ding and Lehrer, 2006; Zimmerman 2003; Vandenberghe, 2002; Hoxby, 2000; Sacerdote, 2001; Zimmer and Toma, 2000). Moreover, a number of these studies show that peer effects are often non-linear, implying that students of middle abilities are particularly affected by the negative influence of weak students (Sacerdote, 2001; Zimmerman, 2003). However, the significance and size of peer effects often changes in relation to the sample used. Other studies, in fact, find no significant (or minor) peer effects (Angrist and Lang, 2004; Arcidiacono and Nicholson, 2005; Foster, 2006).

Earlier analyses of peer effects were based on simple econometric models regressing students outcomes on their own individual characteristics (measures of ability, family background and so on) and on their peers' outcomes or characteristics.

As shown by Manski (1993), this kind of regression is plagued by two main econometric problems, which raise doubts about the causal interpretation of the coefficient measuring peer group effects. The first problem, known as "self-selection" bias, depends on the fact that groups of peers are often not exogenously determined, but individuals typically choose the other people they will associate with . Therefore, the characteristics of each student contribute to determining the choice of his/her peers and, if some of these characteristics are not observable, an endogeneity problem arises.

The second econometric problem, known as the "reflection" problem, emerges because the outcomes of students in a peer group evolve in an interdependent manner: the achievements of each member affects the achievements of other members but, at the same time, is, itself, affected by the achievements of those self-same peers. Therefore, an estimation bias emerges, due to simultaneity and inverse causality.

Recent empirical studies have undertaken a variety of estimation strategies to handle these problems. A strategy used by a number of researchers is that of relying on some sort of natural experiment which brings about random assignment of peers. Sacerdote (2001), Zimmerman (2003) and Foster (2006) analyse peer group effects among undergraduate students who are randomly assigned to a college residence. Recently, De Giorgi, Pellizzari and Redaelli (2006) have used random assignment to teaching classes as identification strategy to estimate peer effects on the choice of the field of study. Other works rely on instrumental variables to remove the correlation between unobserved characteristics and peer characteristics trying to find exogenous determinants of peer quality (Evans, Oates and Schwab, 1992; Case and Katz, 1991). A number of papers try to take into account the endogeneity of the peer group by controlling for school and individual fixed effects (Arcidiacono and Nicholson, 2004; Hanushek *et al.*, 2003).

Most of the works on peer effects among college students use data from (highly selective) US universities, whereas few works have analysed peer effects in European universities. Our analysis is an attempt to reduce this gap by providing evidence of peer effects among students of a middle sized Italian university located in the South of the country. Importantly, while most of the work on peer effects in tertiary education considers residential peer groups emerging among roommates, we are able to analyze the effects produced on student performance by interaction among students who share the same teaching environment and study together.

Thanks to a rich administrative dataset of students enrolled in the Second Level Degree ("Laurea Specialistica")[1] course in Business Administration at the University of Calabria, we are able to build different definitions of the peer groups, mainly based on students attending classes together and sitting their exams in the same session. This allows us to investigate peer group effects which operate among classmates through mechanisms which rely on the fact that classmates contribute to the shaping of their educational environment and that students typically interact and establish friendly relationships with students attending lectures in the same classes.

Classmates with high abilities help create a more effective learning process: instructors are not interrupted by students asking silly questions and are able to use more challenging material, in addition they are encouraged in their teaching activity by interested and clever students etc. (see Lazear, 2001). We consider this kind of effect through a measure of a peer group based on students attending courses together. For each student *i* we consider, as members of his/her peer group, those students who have taken courses together with *i*. Peer group quality is then calculated as the weighted average of abilities of students in the group, using the number of courses taken together as weights.

Apart from peer effects related to the classroom environment, students belonging to the same class tend to study and revise the subject together, so generating important externalities. Clearly friendly relationships do not involve all members of a class: some students might attend a course together, but their interaction might still be limited. We are able to address this problem by considering a measure of peer group which weights peers in relation to the number of exams taken together. In fact, students who continually do exams in the same session as one another are often students who study together, sharing course material and information. We look at all the students passing an exam on the same date and we use this information to define a second measure of peer group quality, which weights the abilities of each student according to

[1] As explained below, Italian University system is organized in two main levels: students first enrol in First Level Degree course and, after graduation, they may choose to enrol in a Second Level Degree course.

the number of exams taken together with student *i*.[2]

We are aware that these definitions may be affected by self-selection problems since students choose other people to collaborate with in studying. In order to overcome possible self-selection problems, we use a Two-Stage Least Squares estimation and instrument peer groups through the random (and compulsory) assignment of students to different teaching classes during their First Level Degree course (for a similar strategy, see Foster, 2006).

Our estimations show that peer group abilities have considerable, positive effects on students' academic performance. These effects are not brought about by self-selection and are robust to a variety of definitions of peer group and several measures of abilities. In our preferred Instrumental Variable specification, we find that an increase of one standard deviation in peer group quality (measured as the average ability of students attending the same course) produces an increase in student performance of 0.19 (the OLS estimates show a smaller effect equal to 0.13). This is quite a large effect, since the effect produced by an increase of one standard deviation in the student's own ability generates an increase of 0.54. Effects are slightly higher when we consider our second measure of peer group quality, based on repeated interaction at exams, implying that this measure is able to take into account some relevant interaction taking place among students.

These results suggest that student quality is an important input in tertiary education and that, in order to improve their students' performance, colleges and university should attract high quality students. Our results are consistent with selection policies adopted by many US universities aimed at admitting only the best students. They also support the idea that students applying for highly reputable institutions evaluate not only the high quality of instructors provided, but also the high-quality of peers. Moreover, if student performance is determined, at least in part, by his/her effort then is rational to subsidize good students for the positive externalities they produce.

This paper is organized in the following way. In section 2, data are presented and some descriptive statistics are offered. In section 3, we estimate a simple OLS model. In section 4, we instrument our measures of peer group by using the exogenous assignment of students to different teaching classes as an instrument. Section 5 concludes.

2. Data and Descriptive Statistics

Our analysis is based on administrative data from the University of Calabria, a middle-sized public university located in the South of Italy. It has currently about 31,000 students enrolled in different degree courses and at different levels of the Italian University system, which, since the University Reform of 2001, is organized around two main levels, comprised of First Level

[2] In each academic year Italian students have available several dates to take a given exam (in fact, at University of Calabria 7 sessions are available).

Degrees (3 years legal duration) and Second Level Degrees (2 years). Students who have acquired a First Level Degree can undertake a Second Level Degree.[3] In order to gain a Second Level Degree students have to pass about 20 exams and to write a dissertation, obtaining a total of 120 credits.[4]

We focus our analysis on students enrolled, for the academic years 2004-2005 and 2005-2006, on the Second Level Degree course in "Business Administration" ("Laurea Specialistica in Economia Aziendale"). The administrative data we have at hand provide detailed information on students' personal characteristics, secondary school and academic results, gender, type of High school attended and final High school grade, province of residence[5], grades obtained on each course and date of each exam, grades obtained in the First Level Degree course, and initial year of enrolment.[6]

We started with a sample of 267 students, but we excluded students who had done fewer than 3 exams and, to render students enrolled in different years comparable, we only considered exams taken in the first year of their Second Level Degree. Moreover, since, in our analysis, we use information about the academic career of students who have acquired their First Level Degree at the University of Calabria, we excluded some observations and our final sample was composed of 212 students.

Table 1 provides descriptive statistics for the sample of students we use. During the first year of the Second Level Degree course, our sample of students passed an average of 7.71 exams per student. Grades range from 18 to 30 and "30 cum laude", which we consider equal to 31. The *Average Grade* over the exams taken by each student is the measure of academic performance which we use as a dependent variable. The mean of *Average Grade* is 27.05 and its standard deviation is 2.06.

About sixty percent of the students were female. 76 students (36%) were enrolled in their second year and 136 in their first. Students mainly came from two different types of High school: Lyceums (about 34%) and Technical and Vocational Schools (about 66%). Final High school Grade (which we denote throughout the paper as *AbilityHS*) ranges from 60 to 100, with a mean of 89.17. The average grade they obtained at exams during their First Level Degree (denoted as *AbilityFirst*) is 25.58. The Final First Degree Grade ranges from 86 to 110 and "110 cum laude" (which we set as equal to 111) and has a mean of 102.96.[7]

In order to define a single index of individual ability (denoted as *Ability*), we undertook a principal component analysis summarizing the different measures of ability which we had

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[3] After Second Level Degree students can enrol in a Ph.D degree.
[4] Each course typically gives 5 credits.
[5] Provinces correspond to the Nuts 3 Eurostat classification.
[6] Data do not provide information on socio-economic and family background.
[7] The Final First Level Degree Grade is calculated on the basis of the average grade obtained at exams. In our regressions, we prefer to use *AbilityFirst* because the Final Grade compresses variability (typically each student with an average grade of 27.5 or more obtains the maximum final grade, "110 cum laude").

available (*AbilityHS*, *AbilityFirst*, Final First Degree Grade, a dummy for the type of High School denoted as *Lyceum*)[8]. Principal component analysis creates linear combinations of the original variables which capture the greatest variance. We only use the first principal component.

Table 1. Descriptive statistics for the sample of students enrolled on the Second Level Degree course in Business Administration

Variables	Mean	Std. Dev	Min.	Max.	Obs.
Average Grade in exams	27.046	2.062	19.667	30.6	212
Number of exams passed	7.707	2.592	3	13	212
Female	0.618	0.487	0	1	212
Year of enrolment	0.358	0.481	0	1	212
Final First Level Degree Grade	102.962	6.762	86	111	212
Average Grade in First Level exams (AbilityFirst)	25.579	1.710	21.682	29.472	212
High School Final Grade (AbilityHS)	89.171	11.387	60	100	212
High School Type: Lyceum	0.340	0.475	0	1	212
Ability	-0.123	1	-2.291	1.915	212

Notes: Grades in each course ranges from 18 to “30 cum laude” (set equal to 31). Final High School Grade ranges from 60 to 100. Final First Level Degree Grade ranges from 66 to “110 cum laude” (set equal to 111).

3. Econometric Estimations of Peer Group Effects

We analyse the influence of peer groups on academic performance assuming that a student’s academic performance is determined by his/her own characteristics and by the performance and characteristics of his/her peers (Sacerdote, 2001). Therefore, we start from the following simple model:

[1] $$Y_i = \alpha + \beta X_i + \phi X_j + \gamma Y_j + \psi z_{ij} + \varepsilon_i$$

where Y_i is the performance of student *i*, X_i is a vector of individual characteristics of *i* (measures of his/her ability and personal characteristics), X_j includes the (predetermined) characteristics of *j*, belonging to the peer group of *i* (“contextual effects” in the definition of Manski, 1993) and Y_j are the outcome of *i*’s peer (Manski’s “endogenous effect”), z_{ij} are common (unobservable) characteristics of the peer group including student *i* (“correlated effects”), ε_i is an error term.

As mentioned previously, this model faces two main econometric problems: “reflection” and “selection” bias. With regards the “reflection” problem, that is the fact that the achievement of student *i*, Y_i, is determined by the performance of his/her peers, Y_j, but, simultaneously, Y_j is determined by Y_i, we follow the literature (see Sacerdote, 2001; Ammermueller and Pischke, 2006), and considering an equation symmetric to [1] for the performance of each student *j* in *i’s* peer group , by substitution, we obtain the following reduced form equation:

[8] These variables have been standardized in the principal component analysis.

$$Y_i = \frac{\alpha(1+\gamma)}{(1-\gamma^2)} + \frac{(\beta+\gamma\phi)}{(1-\gamma^2)} X_i + \frac{(\phi+\gamma\beta)}{(1-\gamma^2)} X_j + \frac{(1+\gamma)\psi z_{ij} + (\gamma\varepsilon_j + \varepsilon_i)}{(1-\gamma^2)}$$

or, more simply:

[2] $$Y_i = \tilde{\alpha} + \tilde{\beta} X_i + \tilde{\phi} X_j + \tilde{\varepsilon}$$

By estimating equation [2], we are therefore unable to recover the structural parameter ϕ and γ and distinguish "endogenous" from "contextual" peer effects, but, in equation [2], we obtain the magnitude of "total peer effects" $\tilde{\phi}$, which is what matters from a policy point of view, although it may be unsatisfactory from a theoretical perspective.

Another important problem, which may lead to a biased and inconsistent estimate of $\tilde{\phi}$ using OLS, is the endogeneity of X_j, due to the fact that individuals typically select people with whom to associate. This clearly contrasts with an ideal situation in which individuals are randomly assigned to different peer groups. If peers are selected according to individual characteristics that affect his/her own level of attainment (but are unobservable to the researcher), we may end up considering as a peer effect something that, instead, depends on the individual's own attributes which are captured through his/her peer group quality.

This issue is particularly relevant for our analysis, since our peer group measures are based on students taking common courses and exams: students with similar characteristics are likely to choose the same courses or to sit a particular exam in the same session. We tackle this problem by using, as an instrumental variable for peer group quality, the random assignment of students to teaching classes, which, we believe, influences peer group formation, but is not correlated to the error term $\tilde{z}_{ij}$, and estimating with the classical Two-Stage Least Squares (Evans, Oates and Schwab, 1992).

We first estimate a single-equation model with Ordinary Least Squares (OLS) assuming that peer group quality is exogenous. In the next Section, we extend the model to deal with the endogeneity problem, treating peer group as a choice variable.

Our dependent variable Y_i is the *Average Grade* in exams taken by student *i* during his/her first year on the Second Level Degree course. In the vector X_i, in turn, different measures are considered of *i*'s own ability: Final High School Grade (*AbilityHS)*, Average Grade in the First Level Degree course (*AbilityFirst*), and a composite index of individual ability (*Ability*)). Other personal characteristics included in vector X_i are: a gender dummy (*Female*), a dummy for the type of High School (*Lyceum*), and dummies for province of residence.

In order to take into account the levels of difficulty of the different courses chosen by each student (or different evaluation criteria used by different lecturers),[9] we control, in each regression, for the average of the grades (*Average Course Grade*) obtained by all other students taking a given exam and consider the average over all of the exams taken by student *i*. Since, as we explain below, our sample students have attended part of their First Level Degree courses in different teaching classes, we control for some quality characteristics of the instructors teaching in each classes which may affect students' performance, such as research activity (*Instructors' Publications*) and teaching experience (*Instructors' Experience*). As these regressors vary at teaching classes level, in order to avoid biased standard errors, we estimate our models clustering the standard errors at this level (Moulton, 1990).

All variables have been standardized in order to make results comparable in different specifications and to render the interpretation of marginal effects more straightforward.

In Table 2, we report estimates of alternative specifications of our model. In all specifications, standard errors (reported in parentheses) are corrected for heteroskedasticity. All equations include province of residence dummies (not reported so as to save space).

In column 1, we first estimate an equation without peer effects to check which factors determine academic performance. We show that *AbilityFirst* greatly explains our dependent variable, while *AbilityHS* is not significant.[10] *Average Course Grade* is positive and highly significant. The *Female* and *Lyceum* dummies are not significant, nor are the dummies for province of residence. Variables measuring teaching quality on the First Level Degree courses show a positive and statistically significant effect.

The other columns in Table 2 include peer group quality among explanatory variables. We use different measures of peer group quality. From a theoretical point of view, it is not clear whether a student is influenced mainly by his/her close friends, or by his/her classmates, or by his/her roommates in college, or by people from his/her place of residence. Our definitions of peer group are at an aggregate level and tend to describe different types of interaction among students.

Our first definition of peer group (*Peer Course*) is based on the group of students who have taken a given course, attending classes and taking the exam in the same academic year. Therefore, in this case, we are assuming that the relevant peer group is represented by people who attend classes together. As shown by Lazear (2001), education in a classroom environment is almost a public good. Weak students may impose negative externalities on other students by disturbing or slowing-down learning and viceversa.

Students on the Second Level Degree course in Business and Administration at the

[9] Students have a certain freedom to choose courses in their Degree program, after some compulsory courses.
[10] This is likely due to the high collinearity between *AbilityHS* and *AbilityFirst* (the correlation rate is 0.56) If we consider *AbilityHS* as the only measure of ability, it is highly significant with a p-value of 0.00 (not reported).

University of Calabria enrol in a wide range of courses. We do not observe directly the composition of students on each course, but we infer this information from exams taken by students in a given year.

For each exam k taken by student i, we first determine the average ability (using different measures: *AbilityHS*, *AbilityFirst* and *Ability*) of all other students taking the same course. Then, we take the average over all the exams taken by i to calculate the ability of i's peer group:

$$Peer\ Course_i = \frac{1}{N_i}\sum_{k=1}^{N_i}\left(\frac{1}{J_k}\sum_{j=1}^{J_k} A_j\right)$$

where A_j is the ability of j, J_k is the number of peers in the exam k, N_i are the exams taken by i. The average number of exams taken by each students is 7.71[11], while the average number of students in each course is 24.82.

Columns 2, 3 and 4 of Table 2 use *AbilityHS*, *AbilityFirst* and *Ability* respectively as a measure of peer ability A_j. In all specifications, controlling for individual characteristics and teaching quality, peer effects appear positive and significant. An increase in the (pre-determined) ability of the peer group of student i (whichever way it is measured) leads to an improvement in the academic performance of i. For example, as shown in column 4, an increase in the ability of the peer group (measured as *Ability*) of one standard deviation leads to an improvent in student performance of about 0.13. The coefficient is significant at 5 percent level.

Smaller effects emerge when we measure peer group ability on the basis of final High School grade or of average grade during the First Level degree course (respectively *AbilityHS* and *AbilityFirst*). As it is possible to see in columns 2 and 3, the coefficient is in, both cases,about 0.06, significant respectively at 10 and 5 percent level.

The other explanatory variables have approximately the same level of significance as in column 1. Student's own abilities, measured by the average grade during the First Level Degree course (or by *Ability*), is, in each specification, positive and highly significant. An increase of one standard deviation of an individual's own ability improves performance by about 0.55. *Average Course Grade* is always significant, implying that courses chosen by students have different degrees of difficulty. Our variables explain more than 50% of total variability.

In column 5, we investigate the existence of non-linearity in peer effects. Using *Ability*, we have created two dummy variables for whether or not peer group quality was in the top 25 percent (*Peer Course Top*), or in the middle 50 percent of the distribution (*Peer Course Middle*). The bottom 25 percent (*Peer Course Bottom*) represents the omitted category. As shown in column 5, students are positively affected by having a peer group of high and medium

[11] We excluded students who have passed less than 3 exams.

quality (statistically significant respectively at 5 and 1 percent level). The magnitude of coefficients is very similar, implying that having a peer group of medium ability instead of one of high ability does not produce any relevant change in student performance. Results do not change when using different measures of ability.

Following Betts and Morell (1999), in column 6, we also verify whether socio-economic characteristics of the community where students come from influence their performance. We introduce an indicator of educational level, measured as the percentage of people living in the area (town or city) where student *i* is resident with a college or a high school diploma (*Population with College or HS*), average income (*Income*), and the unemployment rate in the area (*Unemployment*).[12] These socio-economic characteristics do not seem to play a relevant role in shaping students' performance, since their coefficients are all not statistically significant.

Table 2. OLS regression estimates for academic achievement.
Dependent variable: Average Grade in Second Level Degree course exams

Explanatory Variables	1	2	3	4	5	6
AbilityFirst	0.565***	0.545***	0.541***			0.539***
	[0.062]	[0.058]	[0.056]			[0.069]
AbilityHS	0.074	0.082	0.085			0.092*
	[0.044]	[0.047]	[0.043]			[0.043]
Ability				0.554***	0.558***	
				[0.051]	[0.051]	
Female	0.004	-0.009	-0.015	-0.117	-0.133	-0.009
	[0.038]	[0.043]	[0.044]	[0.067]	[0.101]	[0.051]
Lyceum	-0.003	0.004	0.006			0.001
	[0.106]	[0.103]	[0.102]			[0.111]
Average Course Grade	0.357***	0.344***	0.353***	0.326***	0.304***	0.339***
	[0.027]	[0.029]	[0.027]	[0.027]	[0.048]	[0.022]
Instructors' Publications	0.326**	0.276**	0.233**	0.234	0.344*	0.226*
	[0.099]	[0.082]	[0.083]	[0.119]	[0.201]	[0.096]
Instructors' Experience	0.375**	0.310**	0.259*	0.236	0.363*	0.256*
	[0.112]	[0.097]	[0.102]	[0.139]	[0.204]	[0.102]
Peer Course (AbilityHS)		0.059*				0.064*
		[0.026]				[0.026]
Peer Course (AbilityFirst)			0.065**			
			[0.023]			
Peer Course (Ability)				0.131**	0.558***	
				[0.390]	[0.051]	
Peer Course Middle					0.347***	
					[0.132]	
Peer Course Top					0.330**	
					[0.163]	
Income						-0.028
						[0.048]
Population with College or HS						-0.001
						[0.060]
Unemployment rate						-0.079
						[0.042]
Constant	-0.146	-0.146	-0.138	-0.108	-0.412**	-0.171**
	[0.092]	[0.085]	[0.091]	[0.101]	[0.185]	[0.057]
Adjusted R^2	0.568	0.569	0.569	0.535		0.569
Observations	212	212	212	212		212

Notes: In all regression dummies are included for province of residence. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at teaching classes level, are reported in brackets. The symbols ***, **, * indicate that

[12] We do not consider differences among schools since all students in our sample accomplished their High School in public schools which differ from the program of study (Lyceums or Technical and vocational schools) but do not differ in terms of resources or teacher/pupil ratio, since the system is highly centralized and uniform.

coefficients are statistically significant, respectively, at 1, 5, and 10 percent level.

4. Instrumental Variable Estimations

In OLS estimates in Table 2, we assumed that peer group quality is an exogenous variable. However, individuals typically choose with whom they will associate and so peer quality is, to some extent, endogenous. In this case, a regression of student performance on peer abilities would be biased and inconsistent because of an endogeneity problem. Therefore we have to deal with this problem in order to measure the relevance of peer effects consistently, identifying cases where the peers were assigned essentially randomly (see Evans, Oates and Schwab, 1992; Foster, 2006).

We need to find an instrumental variable Z which must comply with the two usual conditions:

1) the instrument must be correlated with the endogenous variable, that is $Cov(PeerCourse, Z) \neq 0$;

2) the instrument must not affect student academic performance independently, for reasons other than its influence on the formation of peer groups. It is required that the instrument is exogenous, that is $Cov(Z, \varepsilon) = 0$;

We believe that our second definition of peer group (*Peer First Degree*) has these characteristics. *Peer First Degree* is based on the classes attended by students in the first years of their First Level Degree course. Students in our sample were already enrolled at the University of Calabria for their First Level Degree. As a result of the high number of students enrolled in the First Level Degree course in Business Administration (about 600 students), they were assigned to three different teaching classes (Class 1, 2 and 3) for each compulsory course in the first two years on the alphabetic basis of the initial letter of their surnames. Students were required to attend lectures in their designated teaching classes and, moreover, it was in the student's interest to respect this arrangement, because final exams were laid out autonomously by the lecturers teaching each class (notwithstanding common programmes). For each year, we consider as peers all the students attending the same compulsory course as part of the same assigned classes[13] and calculate peer group quality as the average ability of these students (using our three measures of ability).

This definition of peer group, *Peer First Degree,* is likely to determine the quality of peers on the Second Level Degree course since the repeated interactions taking place among students in these classes are relevant to the defining of their peer group composition: students typically tend to associate, make friends, form stable groups and continue studying over the

[13] The average number of peers according to this definition is 40.83.

following years with people who attend the same classes, even during their Second Level Degree course.[14] Therefore, $Cov(PeerCourse, PeerFirstDegree) \neq 0$. Obviously, this aspect can be empirically tested and, as we show below, the coefficient of the instrumental variable *Peer First Degree* in the first-stage regressions is always highly significant and the F-test used to verify that our instrument is not weak is highly supportive.

With regards to exogeneity, the *Peer First Degree* variable is likely to be exogenous given the random assigning to classes according to alphabetical order and the stringent requirements for students to attend these classes.

Moreover, belonging to a given teaching classes should not determine a student's academic performance (except through its influence on the composition of peer groups), since, except for instructors' quality characteristics, for which we control, resources devoted to different teaching classes are the same and the same institutional structure was valid over the two years. For these reasons, we are confident that $Cov(PeerFirstDegree, \varepsilon) = 0$

First of all, in order to check that our instrument is not "weak", we have tested whether the instrument in the first stage regression is significantly different from zero. In the first-stage regression in which the endogenous variable, *Peer Course,* is regressed on the instrument, *Peer First Class*, and all other exogenous variables, the F-statistics, for the test of whether the instrument coefficient is equal to zero, are always well above the threshold value of 10 suggested by Stock and Watson (2003) (F-statistics range from 33 to 140 according to different measures of abilities used).

As a further check that the instrument is not weak, as suggested by Angrist and Krueger (1999), in Table 3, we report results from three different estimates of the reduced-form equation in which the dependent variable is regressed on all the exogenous variables and on the instrumental variable, *Peer First Degree*: in column 1, we use *AbilityHS* as a measure of peer ability, in column 2, we use *AbilityFirst* and, finally, in column 3, we measure ability using the comprehensive index *Ability*. *Peer First Degree* is highly significant in all the specifications, implying both that our instrumental variable is a strong determinant of peer group quality and that the peer group influences a student's academic performance. Instructors' seniority and research productivity (measured respectively as the number of years an instructor has worked in the university system in a permanent position and as the number of published articles in referred journals per year) are not statistically significant.

Table 3. Reduced form equation estimates of academic achievement.
Dependent variable: Average Grade in Second Level Degree course exams

[14] On this aspect see also De Giorgi, Pellizzari and Redaelli (2006).

Explanatory Variables	*1*	*2*	*3*
AbilityFirst	0.549***	0.548***	
	[0.049]	[0.054]	
AbilityHS	0.079*	0.084*	
	[0.039]	[0.042]	
Ability			0.566***
			[0.057]
Female	0.002	-0.006	-0.111
	[0.048]	[0.040	[0.061]
Lyceum	0.001	0.004	
	[0.048]	[0.104]	
Average Course Grade	0.360***	0.360***	0.354***
	[0.028]	[0.028]	[0.028]
Peer First Degree (AbilityHS)	0.104***		
	[0.026]		
Peer First Degree (AbilityFirst)		0.053**	
		[0.018]	
Peer First Degree (Ability)			0.146***
			[0.018]
Instructors' seniority	0.087	0.267**	0.034
	[0.093]	[0.077]	[0.045]
Instructors' publications	0.072	0.229**	0.047
	[0.087]	[0.058]	[0.040]
Constant	-0.136	-0.138	-0.103
	[0.091]	[0.093]	[0.125]
Adjusted R^2	0.572	0.568	0.534
Observations	212	212	212

Notes: Dummies are included in all regressions for province of residence. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at teaching class level, are reported in brackets. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at 1, 5, and 10 percent levels.

Two-Stage Least Squares

In this section, we estimate, using Two-Stage Least Squares, the model explaining student's academic performance using the *Peer First Degree* variable as an instrument for peer group quality.

Before using an instrumental variable estimator, since OLS would be more efficient than IV under the hypothesis that OLS are consistent, one should check whether it is necessary to use IV at all. In order to verify this aspect, we run the Durbin-Wu-Hausman test to verify the endogeneity of *Peer Course* in OLS. We take the residuals from the first stage regression and insert them, as explanatory variables, into an "augmented" structural equation. In many of our specifications, this variable is significantly different from zero (with the exception of the ability measure "Ability First") showing that OLS is not consistent and suggesting the use of IV to address the problem of endogeneity.

Two-Stage Least Squares Estimations results are shown in Table 4. As above, the three columns use *AbilityHS*, *AbilityFirst* and *Ability* respectively as a measure of peer ability.

Panel B of Table 4 shows the results from First Stage regressions for the different peer ability measures. In all the specifications, it emerges that *Peer First Degree* strongly determines the quality of the peer group as measured by *Peer Course*. Moreover, peer group quality is also influenced by a student's own individual abilities.

Panel A shows Two Stage Least Squares estimations. *Peer Course* coefficients are always positive and highly significant, regardless of how ability is measured. In column 1, controlling for Instructors' publications and seniority, if peer group quality (measured by

AbilityHS) increases by one standard deviation then a student's performance improves by 0.24. This coefficient is significant at 10 percent level. In columns 2 and 3, using *AbilityFirst* and *Ability* respectively, an increase of one standard deviation in peer quality leads to an improvement in student performance of 0.09 and 0.19 respectively (significant at 5 and 1 percent levels).

In general, the IV coefficients are higher than the OLS coefficients. This suggests that measurement errors in the quality of peer group – which may bias our coefficient of interest towards zero – are likely to be more important than the problems of reverse causality.

Table 4. IV regressions of student's academic performance
Dependent variable: Average Grade in Second Level Degree course exams

Explanatory Variables	1	2	3
Panel A: Two-Stage Least Squares			
AbilityFirst	0.485***	0.530***	
	[0.083]	[0.051]	
AbilityHS	0.106	0.089*	
	[0.059]	[0.042]	
Ability			0.541***
			[0.055]
Female	-0.051	-0.016	-0.123
	[0.034]	[0.050]	[0.072]
Average Course Grade	0.306***	0.349***	0.317***
	[0.033]	[0.031]	[0.029]
Lyceum	0.022	0.004	
	[0.102]	[0.103]	
Peer Course (AbilityHS)	0.237*		
	[0.099]		
Peer Course (AbilityFirst)		0.089**	
		[0.027]	
Peer Course (Ability)			0.188***
			[0.027]
Instructors' publications	0.124	0.222***	0.163**
	[0.135]	[0.052]	[0.060]
Instructors' seniority	0.117	0.240**	0.145*
	[0.158]	[0.068]	[0.067]
Constant	-0.146	-0.130	-0.099
	[0.079]	[0.087]	[0.101]
Panel B: First Stage Regressions			
AbilityFirst	0.268***	0.202***	
	[0.700]	[0.051]	
AbilityHS	-0.112	-0.058	
	[0.075]	[0.053]	
Ability			0.133***
			[0.047]
Female	0.224	0.116	0.062
	[0.123]	[0.086]	[0.096]
Average Course Grade	0.231***	0.129***	0.194***
	[0.053]	[0.037]	[0.043]
Lyceum	-0.303	-0.001	
	[0.318]	[0.081]	
Peer First Degree (AbilityHS)	0.436***		
	[0.075]		
Peer First Degree (AbilityFirst)		0.600***	
		[0.046]	
Peer First Degree (Ability)			0.775***
			[0.047]
Instructors' publications	-0.220	0.080	-0.616**
	[0.310]	[0.192]	[0.250]
Instructors' seniority	-0.126	0.303	-0.591**
	[0.325]	[0.196]	[0.267]
Adjusted R^2	0.367	0.679	0.611
Observations	212	212	212

Notes: Panel A reports the Two-Stage Least Squares estimates, instrumenting Peer Course using Peer First Degree. Panel B reports the corresponding first stage. Dummies are included in all regressions for province of residence. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at teaching class level, are reported in brackets. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at 1, 5, and 10 percent levels.

Evaluating Peer effects for individuals who study together

Students belonging to the same class tend to study and revise the subject together, so generating important externalities. However, this kind of relationship does not develop between all the members of a class, since, even though attending courses together, some students may not interact with each other. In order to overcome this problem and build a peer group measure (called *Peer Exam*) based on this type of interaction, which we believe particularly relevant, we consider as members of the same group students who sit an exam on the same date. Anecdotal evidence suggests that students who study together tend to take exams together.

In each academic year, students in our sample have 7 different dates available to take a given exam. For each student, we are able calculate how many times he/she meets any other students at exams or, more precisely, how many times they passed an exam on the same date.[15] Students who meet more often at exams are presumably part of the same group. Therefore, we calculate the ability of the peer group as a weighted average of "matched" students' abilities (with the three measures: *AbilityHS, AbilityFirst and Ability*), using the number of matches at exams as weights:

$$PeerExam_i = \frac{1}{M_i}\sum_{j=1}^{n_i} m_{ij} A_j$$

where A_j is the ability of student *j*, m_{ij} is the number of times student *i* met student *j* at exams, n_i is the number of students met by *i*, and $M_i = \sum_{j=1}^{n_i} m_{ij}$ is the total number of matches of *i*.

This measure of peer group ability weights the ability of each member of the peer group according to the number of exams taken together: students who are found to have often sat exams together are given a higher weight, while those who match less frequently are weighted less.[16] A similar strategy to building a peer group is followed by Bayer *et al.* (2007)[17] and De Giorgi, Pellizzari and Redaelli (2006).

Columns 1, 2 and 3 in Table 5 use *Peer Exam*, calculated using our alternative measures of ability, and instrument this variable (which we strongly suspect to be endogenous), again using *Peer First Degree*. The Durbin-Wu-Hausman test shows that OLS would not be

[15] Unfortunately, we have data on passed exams only, as no information is available regards failed exams.
[16] We also experimented with a measure of peer group which excludes from the peer group all students sitting together only once or twice (because this meetings could be due to pure chance). Results are similar to those reported.
[17] Bayer *et al.* (2004) examine peer effects in criminal behaviour and build peer group as a weighted average of peer's characteristic, using as weight the time spent by individuals together in the same prison.

consistent (for example, using *Ability*, the t-statistics of residuals in the augmented structural regression is equal to 3.12) and support the use of IV to address the problem of endogeneity.

Through this new definition of peer group, our previous results with regards the relevance of peer effects are confirmed. In fact, the results show that: (a) *Peer First Degree* determines the formation of a peer group (as shown by the high significance of the relative coefficient in first stage regressions and by the test for weak instruments for which F-statistics takes on values from 26 to 170) and that (b) peer group quality is an important determinant of a student's academic performance (regardless of how abilities are measured). In column 1, we show that if *Peer Exam* measured using *AbilityHS* increases by one standard deviation, then a student's academic performance improves by 0.26 (the coefficient is significant at 5 percent level). Analogous results are obtained if we use alternative measures of peer group abilities. For example, using *Ability*, we find that an increase of one standard deviation in the peer group quality leads to an improvement of 0.28 in the student's academic performance (significant at a 1 percent level).

These coefficients are slightly higher compared to those obtained by considering all students attending courses together as peer groups, implying that students' performance is more highly influenced by colleagues with whom they interact more frequently.

Table 5. IV regressions of student's academic performance
Dependent variable: Average Grade in Second Level Degree course exams

Explanatory Variables	1	2	3
Panel A: Two-Stage Least Squares			
AbilityFirst	0.520***	0.534***	
	[0.062]	[0.056]	
AbilityHS	0.051	0.069	
	[0.057]	[0.051]	
Ability			0.494***
			[0.075]
Female	0.003	0.002	-0.079
	[0.049]	[0.044]	[0.078]
Average Course Grade	0.310***	0.360***	0.313***
	[0.037]	[0.031]	[0.036]
Lyceum	0.021	0.004	
	[0.101]	[0.111]	
Peer Exam (AbilityHS)	0.263**		
	[0.098]		
Peer Exam (AbilityFirst)		0.097**	
		[0.034]	
Peer Exam (Ability)			0.282***
			[0.045]
Instructors' publications	0.191	0.248***	0.192***
	[0.095]	[0.048]	[0.025]
Instructors' seniority	0.185	0.271***	0.165***
	[0.113]	[0.067]	[0.027]
Panel B: First Stage Regressions			
AbilityFirst	0.112	0.139***	
	[0.072]	[0.068]	
AbilityHS	0.106	0.153	
	[0.076]	[0.071]	
Ability			0.256***

			[0.059]
Female	-0.002	-0.080	-0.115
	[0.125]	[0.116]	[0.121]
Average Course Grade	0.191***	0.002	0.145**
	[0.054]	[0.050]	[0.054]
Lyceum	-0.077	0.020	
	[0.119]	[0.058]	
Peer First Degree (AbilityHS)	0.394***		
	[0.077]		
Peer First Degree (AbilityFirst)		0.600***	
		[0.046]	
Peer First Degree (Ability)			0.518***
			[0.080]
Instructors' publications	-0.453	-0.199	-0.516
	[0.316]	[0.259]	[0.314]
Instructors' seniority	-0.374	-0.038	-0.464
	[0.331]	[0.264]	[0.335]
Adjusted R^2	0.268	0.373	0.377
Observations	212	212	212

Notes: Panel A reports the Two-Stage Least Squares estimates, instrumenting Peer Course using Peer First Degree. Panel B reports the corresponding first stage. Dummies are included in all regressions for province of residence. Standard errors, corrected for heteroskedasticity and adjusted for potential clustering at teaching class level, are reported in brackets. The symbols ***, **, * indicate that coefficients are statistically significant, respectively, at 1, 5, and 10 percent levels.

5. Concluding remarks

A large amount of empirical literature shows that peer group quality has important effects on a student's performance and, more in general, on an individual's results. While, for primary and secondary education, there is considerable literature analyzing the effects of classmates' quality on student performance, for tertiary education, research is mainly focused on residential peer effects emerging among roommates and little is known about the effects produced on college students by different teaching environments.

Thanks to a rich administrative dataset, we are able to build different definitions of the peer group, mainly based on students attending classes together, interacting in study activity and sitting their exams in the same session. This allows us to investigate peer group effects which occur among classmates through mechanisms which rely on the fact that classmates contribute to the shaping of the educational environment.

In addition, most research on peer group effects in education is focussed on the US, whereas very few studies examine European schools or universities. To our knowledge, this paper is the first attempt to evaluate peer effects in an Italian university.[18] Moreover, whereas many papers study highly selective universities with rather homogeneous groups (see Sacerdote, 2001), the students we consider are not sorted through a selection process and are highly heterogeneous in terms of abilities. This factor, which widens variability, is likely to increase the relevance of peer effects.

We regress the student's Average Grade in the Second Level Degree course on his/her own predetermined characteristics and abilities and on his/her peers' abilities. We use a variety of definitions of peer group – based on the courses taken together, on classes attended during

[18] De Giorgi, Pellizzari and Redaelli (2006) examine for a prestigious Italian university the influence of peer groups on the choice of majors, rather than on academic performance.

the First Level Degree course, on the dates of exams– and use different measures of abilities (Final High School Grade, Average First Level Degree Grade, type of High School etc.). It is likely that the peer group, defined both in terms of classes attended and of exams taken together, will encompass the relevant interactions among students.

In order to overcome the reflection problem, one of the main econometric problems that affects estimates of peer effects, we use predetermined variables for abilities, but do not attempt to distinguish the channels through which peer group influences a student's performance. From a policy point of view, this is not particularly detrimental.

The second econometric problem in estimating peer effects is the endogeneity of the peer group, in that individuals tend to choose people with whom to associate. In order to solve this issue, we estimate a model with Two-Stage Least Squares, using, as an instrument for peer group, the teaching classes to which students were assigned within compulsory courses during their First Level Degree.

Our results show very clearly that peer effects are positive and substantial. Being part of a group with higher abilities considerably improves a student's academic performance. Results are robust to different definitions of a peer group and different measures of ability used.

Peer group effects emerging from our analysis are, in most of the specifications, larger in magnitude than those shown in other studies (Sacerdote, 2001; Zimmerman, 2003). This could be due to the fact that our measure of peer group quality includes interactions among students – based on attending the same classes, sharing the same educational environment and studying together – which are likely to be greater than those deriving from sharing the same accommodation . In fact, people sharing the same room may have limited interaction due to the fact that they specialise in different areas and have different interests. On the other hand, students attending the same courses or working together establish relationships that are crucial in determining effective learning processes.

According to our results, student quality is an important input in tertiary education implying that attracting high quality students helps colleges and universities to improve their students' performance. Positive effects produced by high quality peers are consistent both with the highly selective policies adopted by many US universities and the high fees that students are willing to pay to be admitted to these universities.

Peer effects by definition imply positive or negative externalities which lead individual choices to be different from optimal social choices. If we realistically assume – following the analysis of Costrell (1994) and Kremer, Miguel and Thorntorn (2007) – that student ability is not only due to genetic factors, but is also the outcome of student effort during his/her educational career, our results suggest that high achieving students should be subsidized (through scholarships and grants) for the positive externalities they produce on other students. On the other hand, students who perform badly may be encouraged to increase their sub-optimal level of effort by tuition fees which are inversely related to their academic performance (Garibaldi *et al.*, 2007).

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